A Decade of X-Vehicles: Lessons Learned

by
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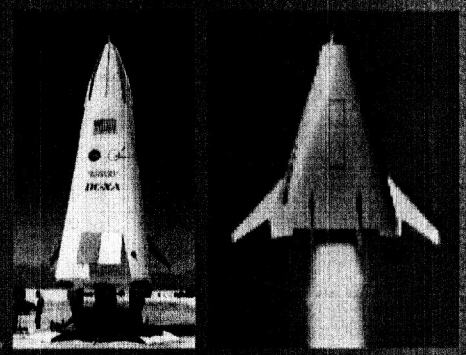


NASA

Space Transportation Directorate

Forward

- **This material was originally Task 1 of a Study initiated in 2001 following cancellation of X-33 and X-34 Programs**
  - The final report was issued in September 2002 titled "A Structured Approach to RLV Technology Flight Testing"

- **An interim version of this material was released by NASA procurement in January 2002 prior to submission of NRA8-30 cycle II proposals**

- **Task 1:**
  - Collect lessons learned from successful and unsuccessful X-Vehicle programs conducted by DoD and NASA during the 1990s.
  - Evaluate data to determine broad/cross cutting reasons for success.
  - Propose guidelines that will promote successful future NASA X-Vehicle Programs.

Approach

- **1) Contact program personnel for recent X-Vehicle Programs and request their assistance in study**
  - DC-X — Jess Sponable
  - DC-XA — Dan Dumbacher
  - X-33 — Dan Dumbacher
  - X-34 — Mark Fisher
  - X-36 — Gary B. Cosentino
  - X-37 — Dick Cervisi
  - X-38 — John Muratore
  - X-40 — Dick Cervisi
  - X-40A — Dan Mitchell
  - X-43A — Chuck McClinton

- **2) Request lessons learned from each program**
- **3) Request contract, budget, and management data, including customer relationship information**
- **4) Evaluate data to identify broad/cross cutting reasons for success**
- **5) Propose guidelines for future program success**

Traditional Aircraft X-Vehicle Programs

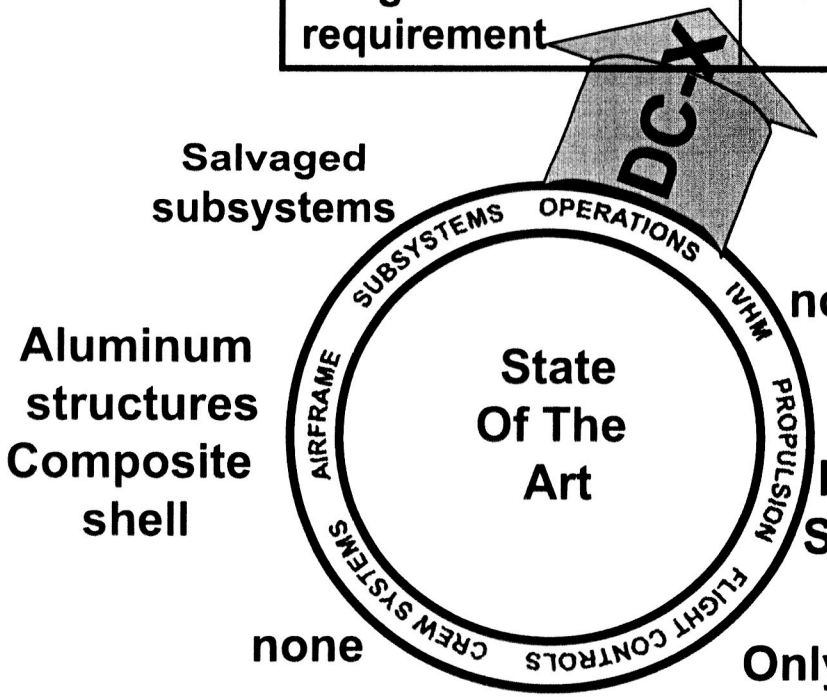
- **Early X-Vehicles created to "expand the flight envelope"**
- **Early envelope expansion aimed at higher and faster**
  - X-1 through X-15
  - 1950s through 1960s
- **Later Expansion efforts turned to other measures of flight performance**
  - Turn-radius
  - Time to climb
  - Sustained cruise mach number
  - Agility
  - Stealth
  - 1970s through 1990s

1990s Space Related X-Vehicles

- **Higher, faster, shorter transit times no longer the figure of merit**
- **Mission cost became the dominant factor in the 1990s**
- **Safety and reliability became the dominant factors in determining mission cost**
- **The application of new technologies to new flight vehicles was favored approach to move the launch industry from the current SOTA to a new operating capability**
- **The Air Force and NASA initiated a number of X-Vehicles to demonstrate the required technologies**
  - DC-X, DC-XA, X-33, X-34, X-37, X-38, X-40, X-40A
- **Each of these is an attempt to expand the technology envelope**

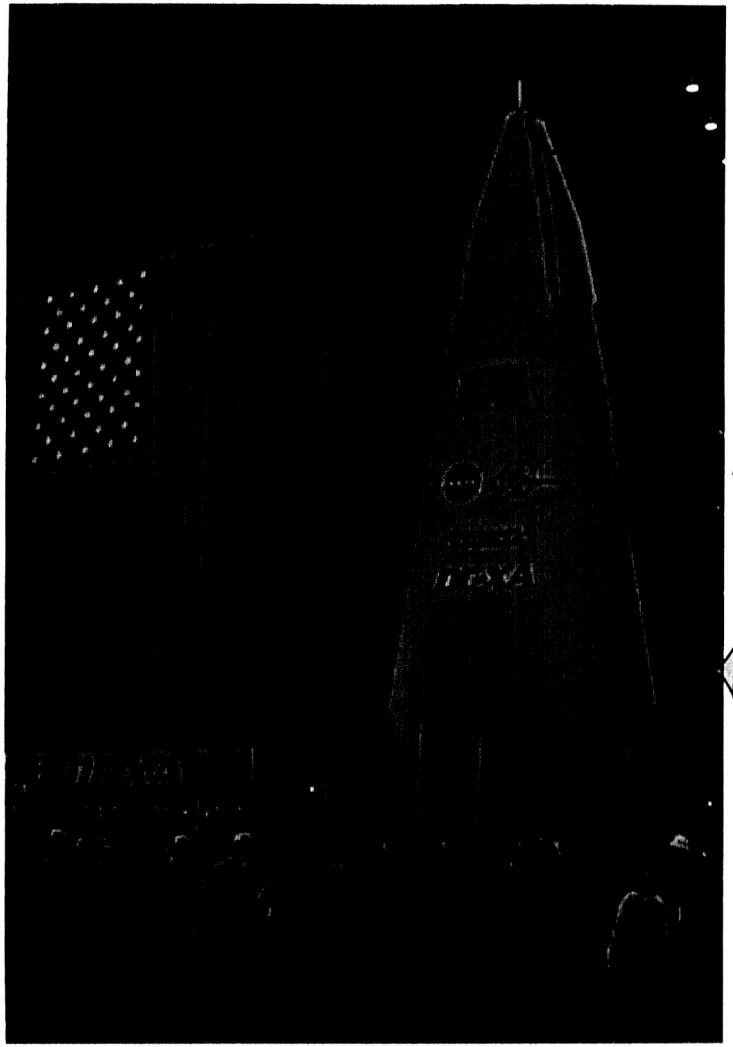
DC-X "The Operations Demonstrator"

Contract Type/ Approximate Value	Cost/$45M -$65M
Schedule	2 years to Flight
Customer	SDIO/BMDO/AFRL
Integration requirement	None



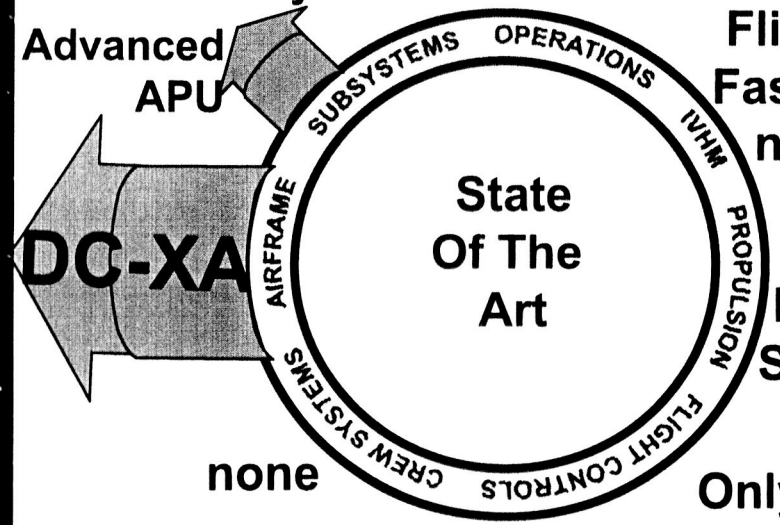
DC-XA "NASA's Technology Demonstrator"

Contract Type/ Approximate Value	Cooperative Agreement/$50M
Schedule	2 years to Flight
Customer	NASA
Integration requirement	None



Salvaged subsystems

Advanced APU



3 man Operations Team
10 man Maintenance & Flight Prep Team
Fast Turn Around
none

RL10s Modified for Sea level ops

none

Only what was Required to support Ops demo

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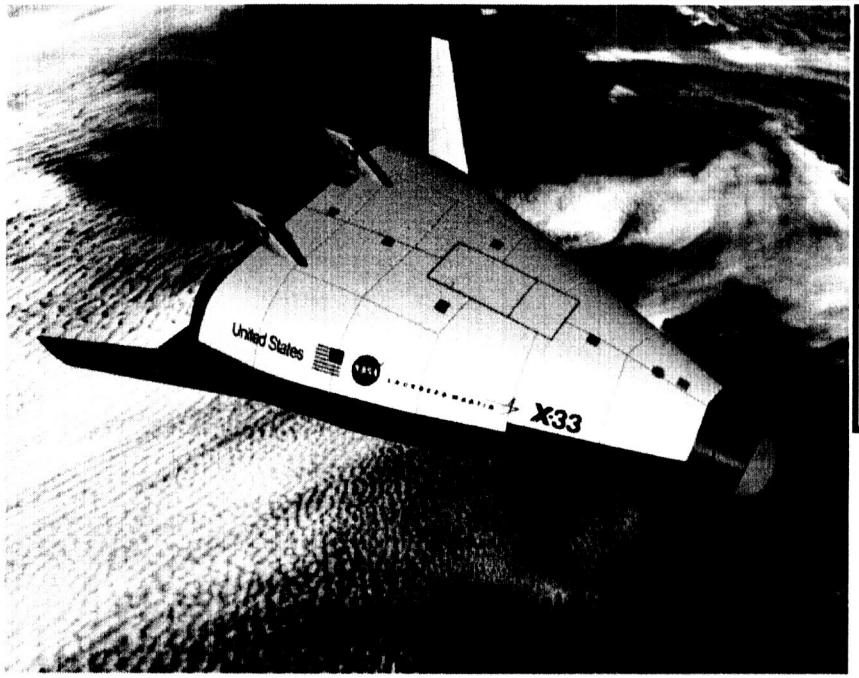
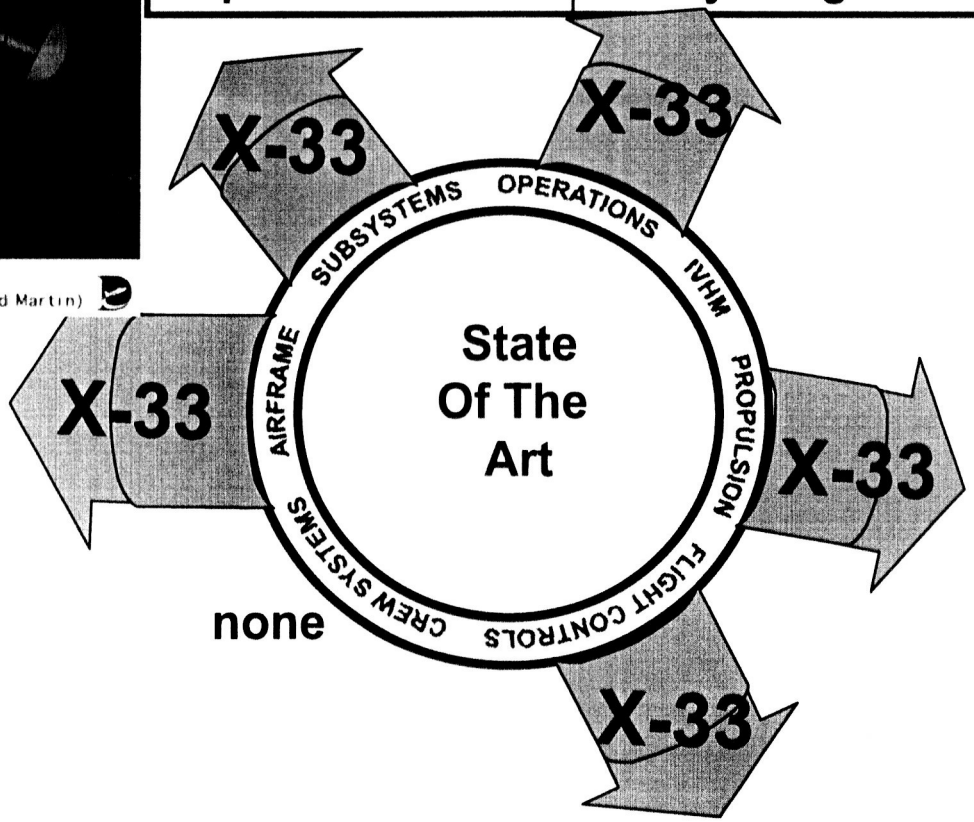
X-33 "NASA's Precuursor to SSTO Operations"



Dryden Flight Research Center ED97-43938-3
X-33 Reusable Launch Vehicle (Artist concept courtesy of Lockheed Martin)

Contract Type/ Approximate Value	Cooperative Agreement/ $850M
Schedule	3 years to Flight
Customer	NASA
Integration requirement	Complete ground facility/Range Developed



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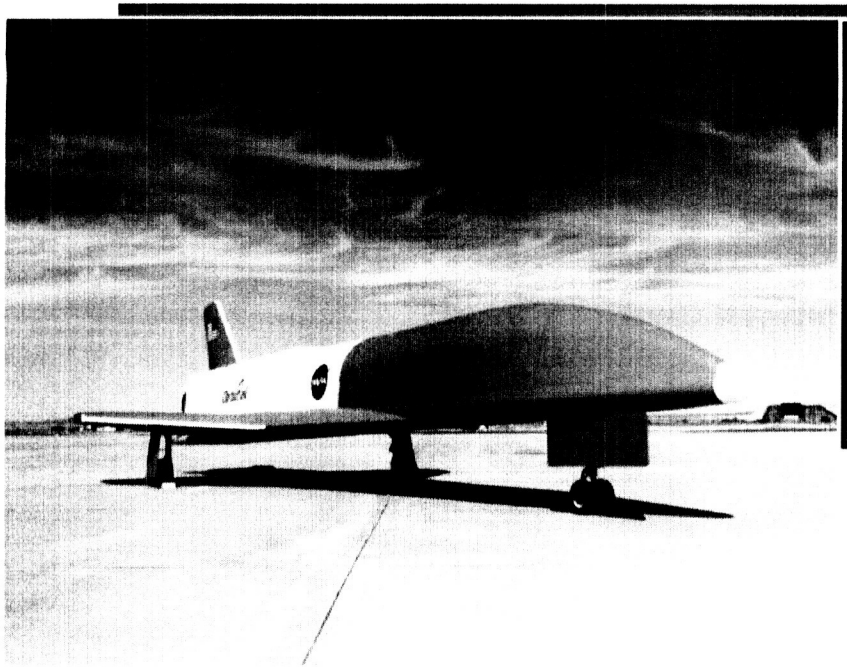
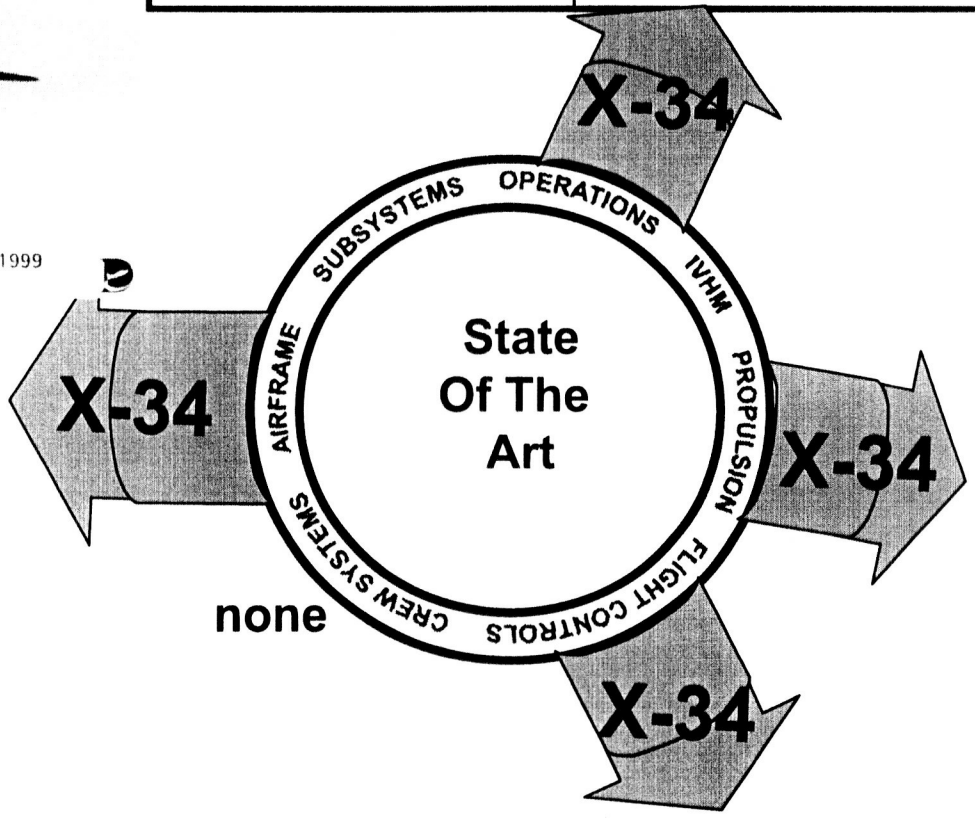
X-34 "NASA's Technology Bridge to the X-33"



Dryden Flight Research Center EC99 44976-8 Photographed 16APR1999
X-34 on Dryden ramp NASA/Dryden Tony Landis

Contract Type/ Approximate Value	Fixed Price Contract/ $65M-$120M
Schedule	2.5 years to Flight
Customer	NASA
Integration requirement	L-1011 Integration required



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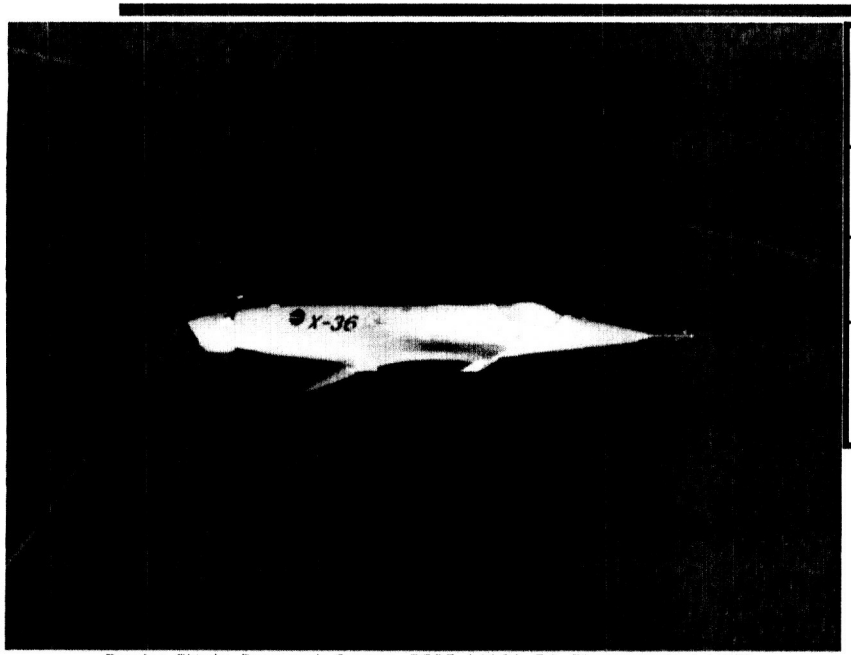
X-36 NASA's "Tail-less Fighter" Demonstration



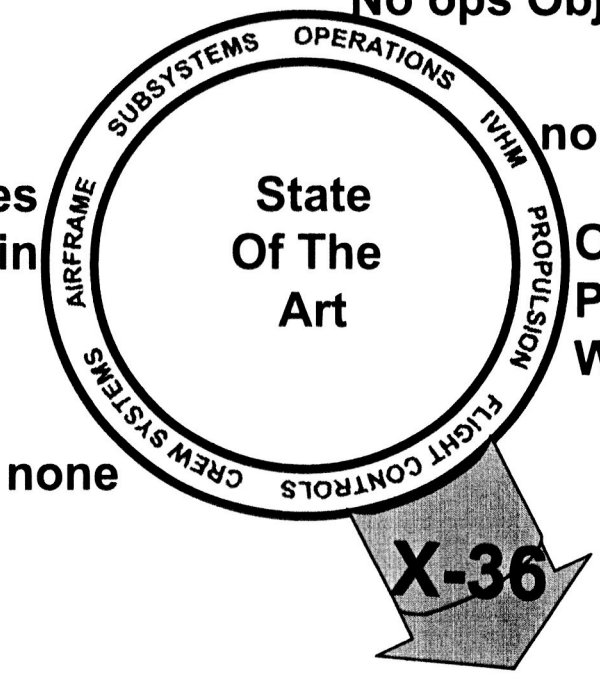
Dryden Flight Research Center EC97 44121-24 Photographed 1997
The NASA/McDonnell Douglas X-36 remotely piloted aircraft flies over the Mojave desert near NASA Dryden Flight Research Center, Edwards, Calif., during its 5th flight, on June 26, 1997. (Ross/NASA)

Contract Type/ Approximate Value	Task Order Contract/ $17M-$21M
Schedule	2-3 years to Flight
Customer	NASA
Integration requirement	Proprietary Subsystems involved

Subscale vehicle
No ops Objectives

none

Aluminum Structures
Composite Skin



Off the shelf
Propulsion
Williams F112

none

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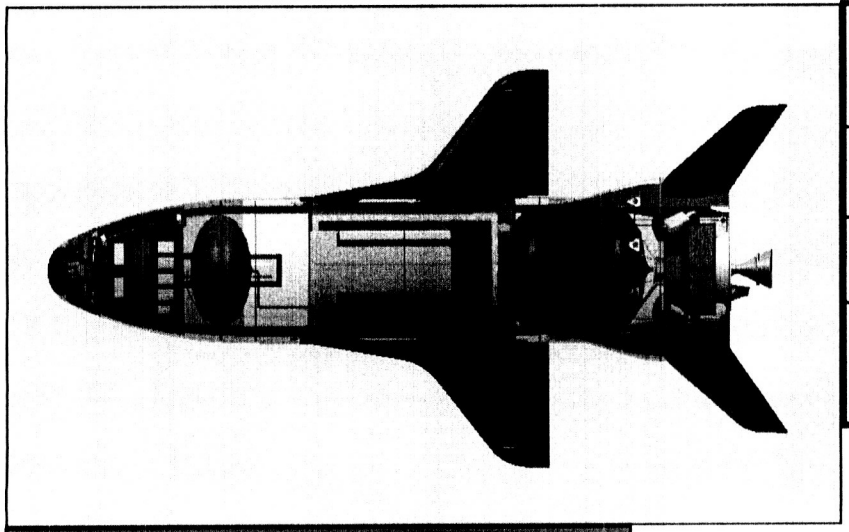
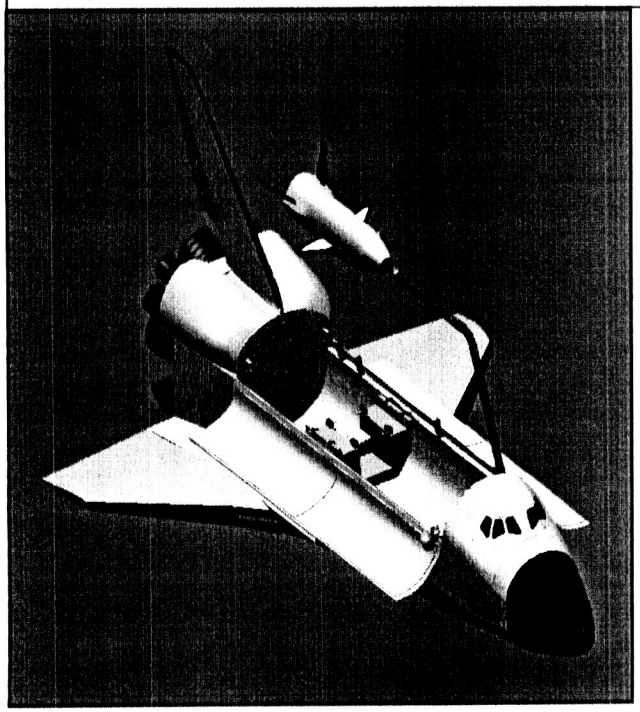
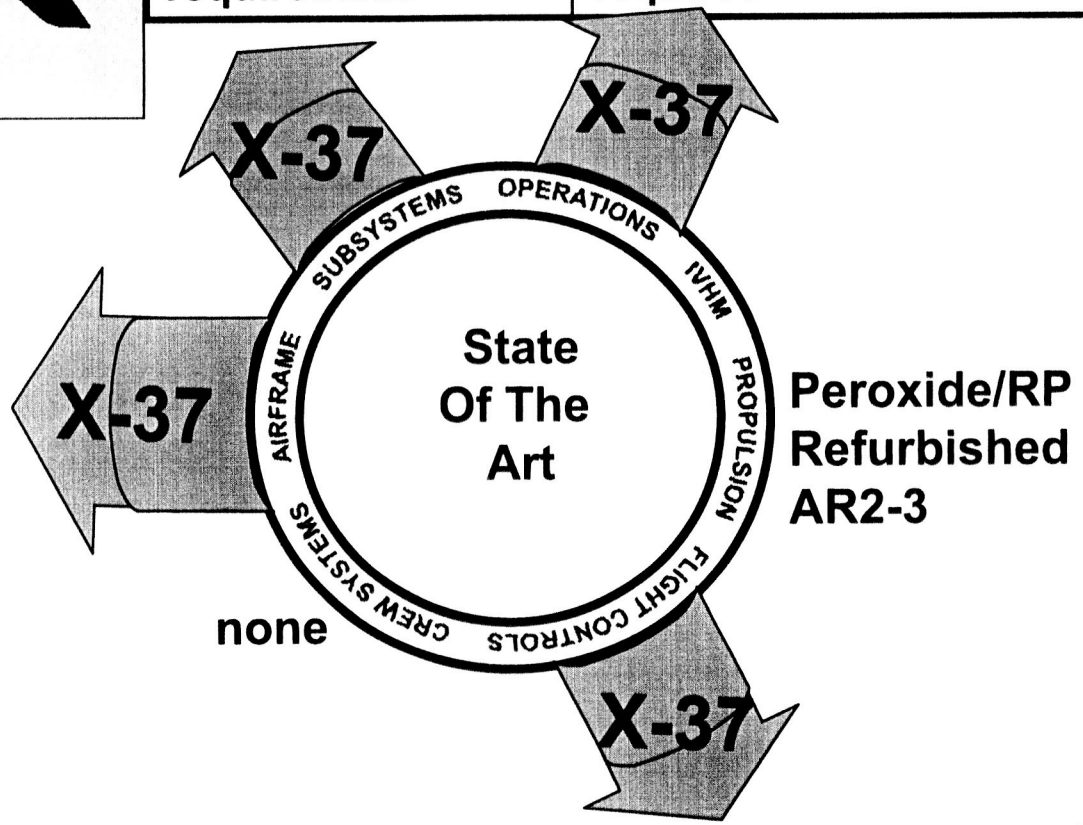
X-37 "The first of NASA's New era of X Vehicles"



Contract Type/ Approximate Value	Cooperative Agreement/ $140M
Schedule	3 years to Flight
Customer	NASA/AFRL
Integration requirement	Shuttle Integration required





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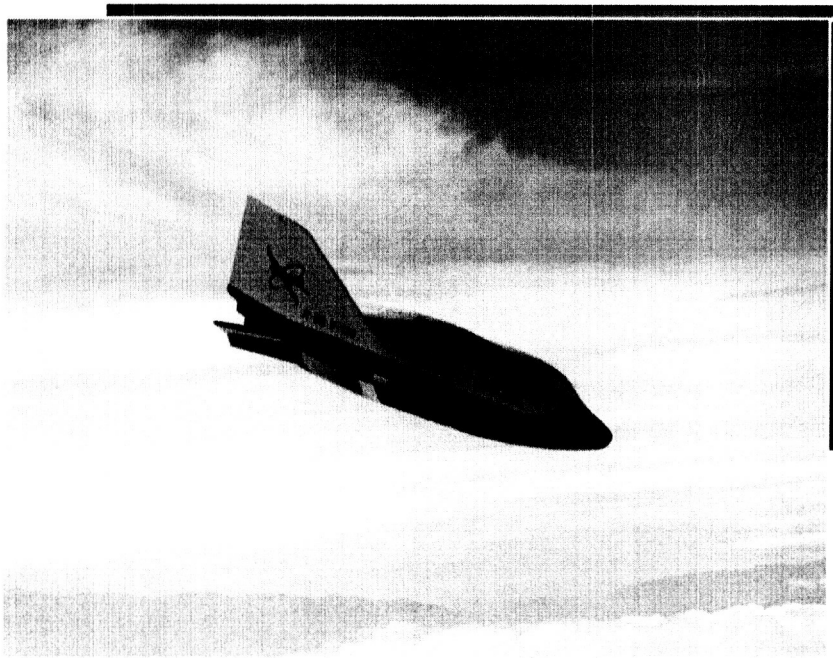
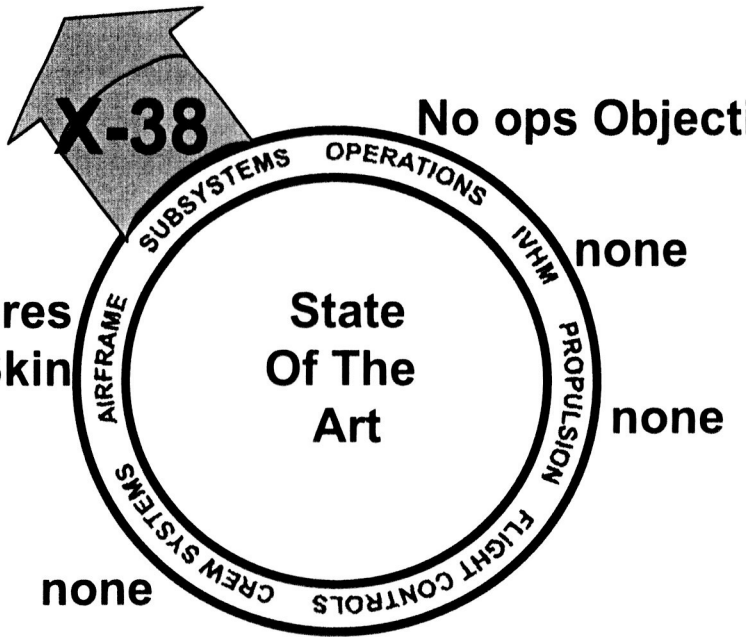
X-38 NASA's "Crew Return Landing System Demonstrator"



NASA Dryden Flight Research Center Photo Collection
http://www.dfrc.nasa.gov/gallery/photo/index.html
NASA Photo: EC99-45080-21 Date: July 9, 1999 Photo by: Carla Thomas

X-38 Ship #2 in Free Flight

Contract Type/ Approximate Value	Multiple cost contracts
Schedule	2 years to Flight
Customer	NASA
Integration requirement	B-52 Integration

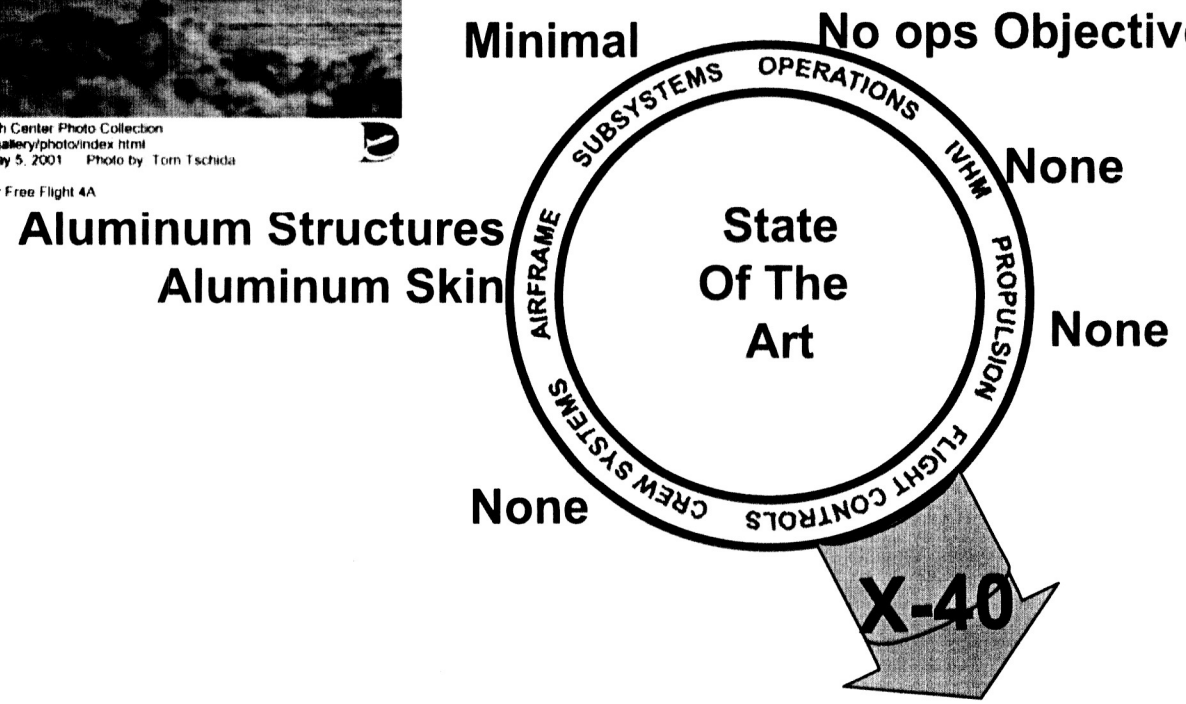


X-40 AFRL's "Autonomous Landing Demonstrator"

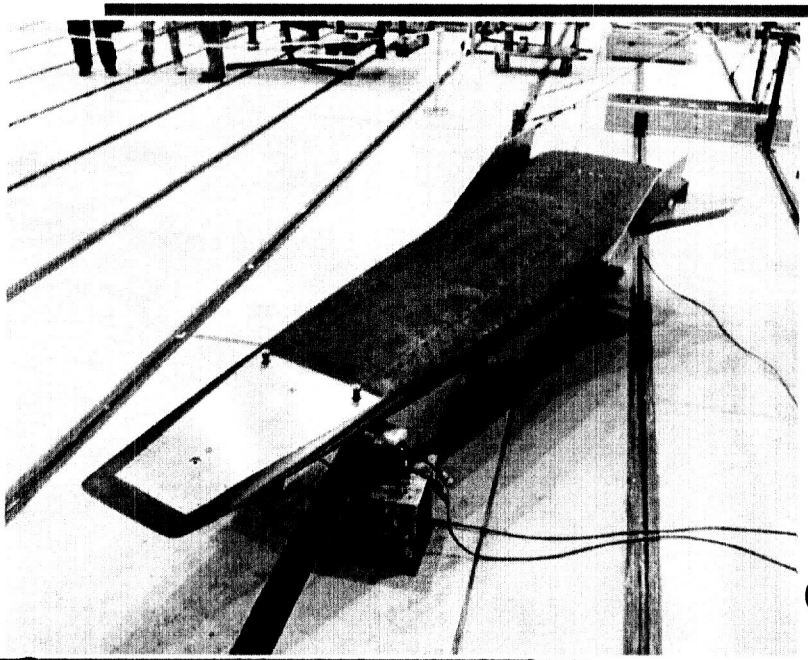
NASA Dryden Flight Research Center Photo Collection
http://www.dfrc.nasa.gov/gallery/photo/index.html
NASA Photo: EC01-0145-12 Date: May 5, 2001 Photo by: Tom Tschida

X-40A landing after Free Flight 4A

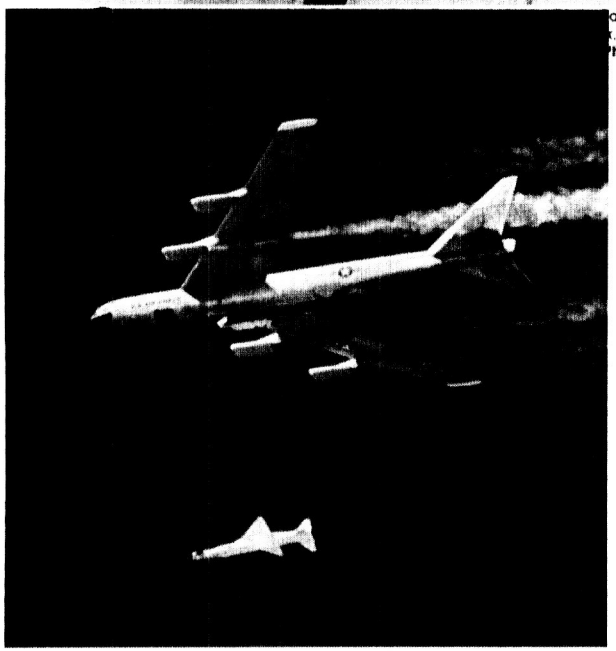
Contract Type/ Approximate Value	Task Order Contract/ $8M-$12M
Schedule	2 years to Flight
Customer	AFRL
Integration requirement	Helicopter integration required



X-43A NASA's "Hypersonic Research Vehicle"



Contract Type/ Approximate Value	Cost Plus Contract/ $168M-$210M
Schedule	5 years to Flight
Customer	NASA/AFRL
Integration requirement	Pegasus/B52 integration Required



ollection
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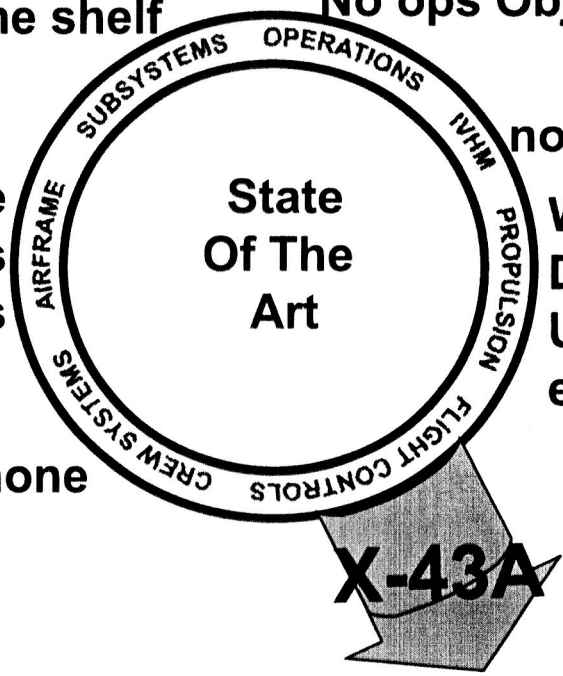
hoto by Tom Tschida

Subscale vehicle
No ops Objectives

Off the shelf



none

SOTA airframe
Design Practices
And materials

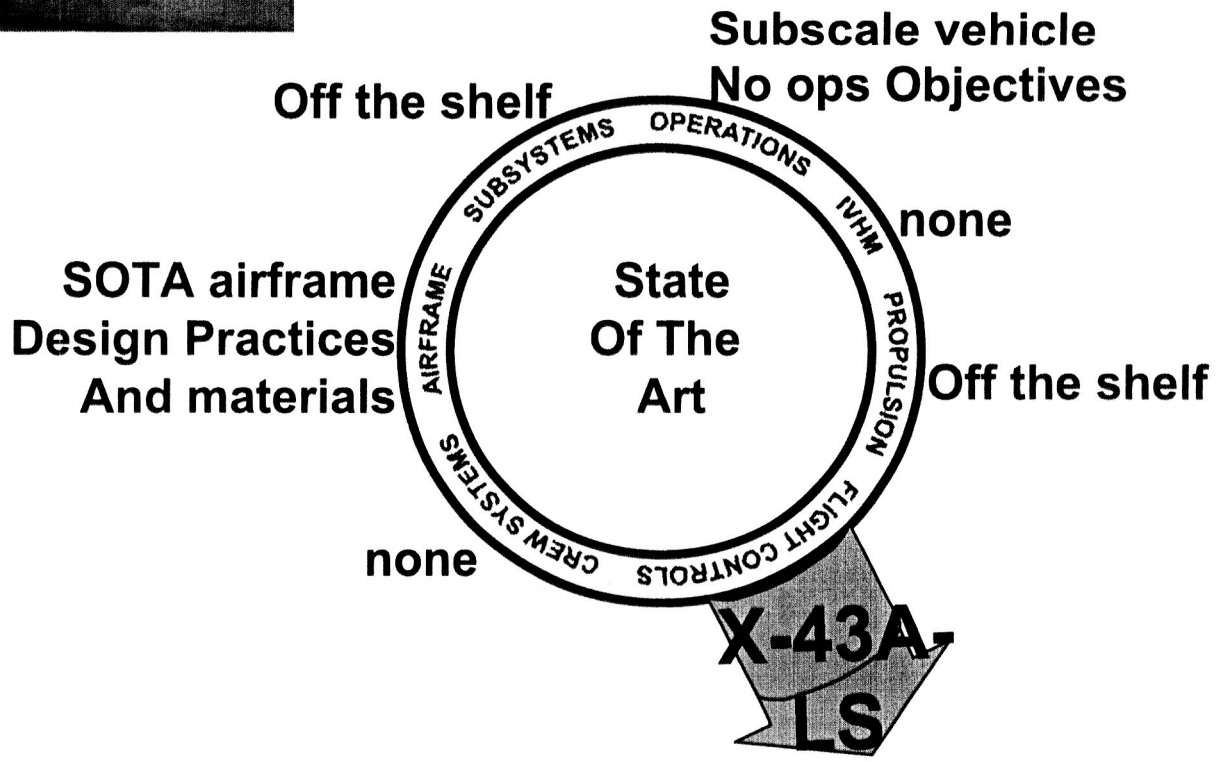
none

Wind tunnel
Derived
Uncooled
engine

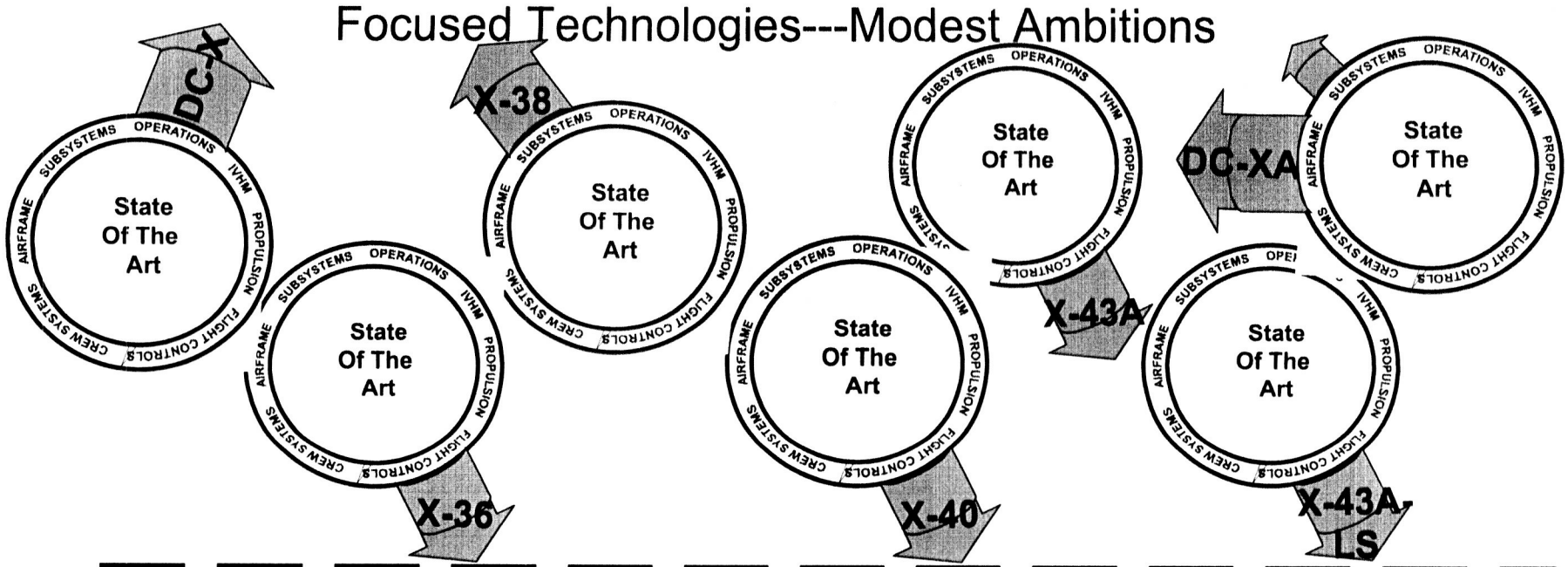
5979.14

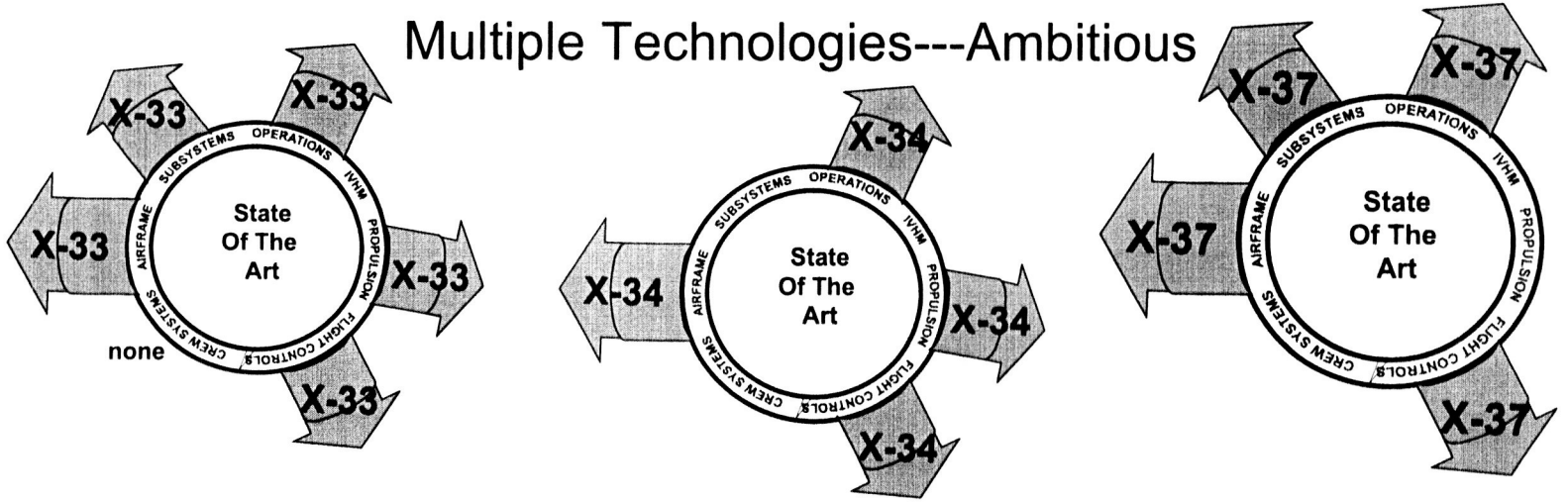
X-43A-LS NASA's "Low speed Blended Body Research Vehicle"

Contract Type/ Approximate Value	Fixed Price SBIR/ $675K-$1.1M
Schedule	3 years to Flight
Customer	NASA
Integration requirement	None

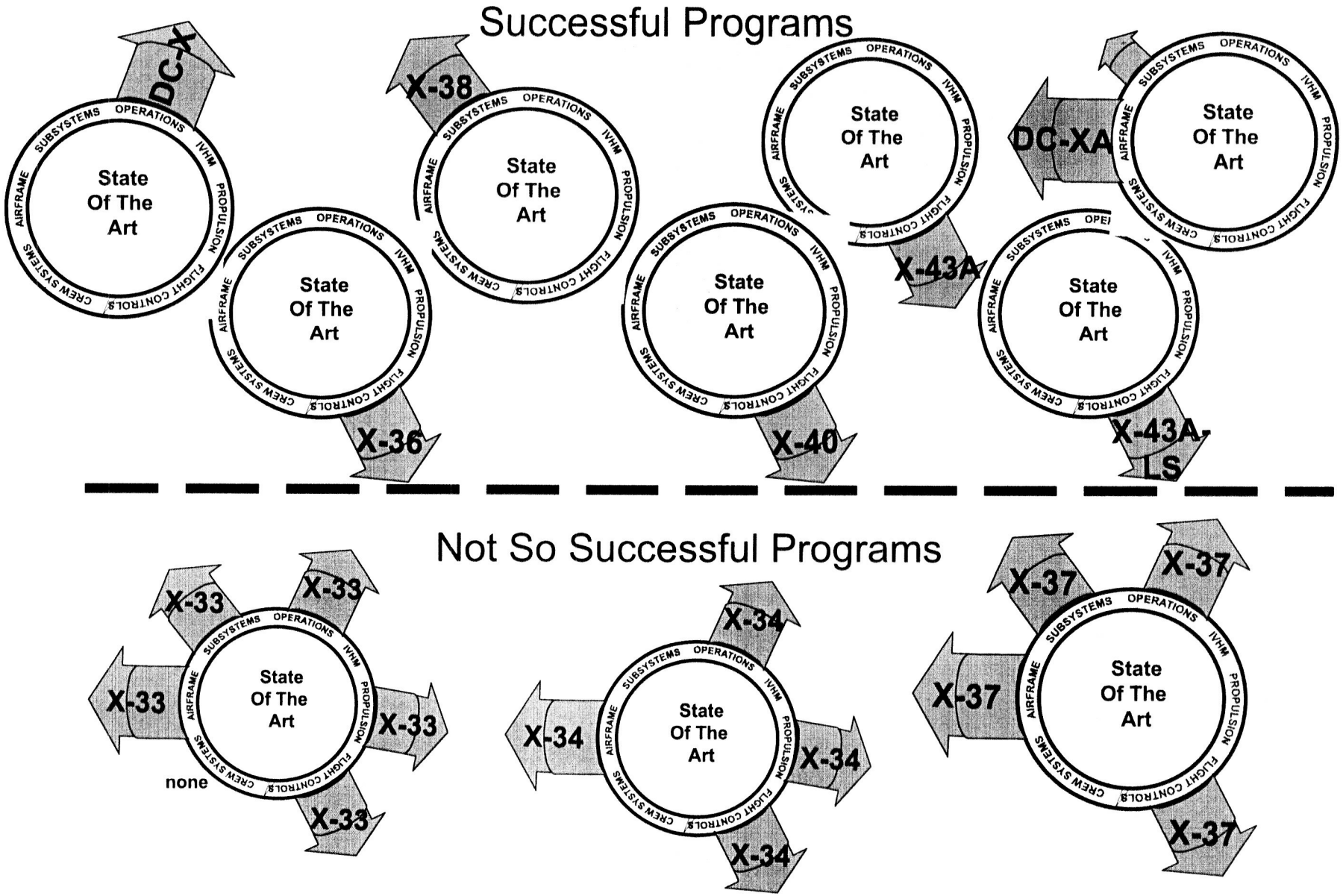


Two Tiers of X-Vehicles Emerge





Two Tiers of X-Vehicles Emerge



X-Vehicle Guidelines (1&2)

- **1) X-Vehicles should have a focused technology thrust**
  - All other technologies incorporated into the air vehicle should be SOTA or less. All other technologies should represent little or no risk to successful program performance

- **2) Modification of, or scale up from, existing vehicles substantially lowers risk**
  - DC-X ⇒ DC-XA
  - X-24 ⇒ X-38
  - X-40 ⇒ X-40A ⇒ X-37 ALTV (De-scoped)

X-Vehicle Cost Growth

- **Cost growth on successful and unsuccessful X-vehicle programs ranged from -10% on DC-XA to over 100%**
- **Average of data available is 46% cost growth**

Guideline number 3 for successful Program execution---

- **3) X-Vehicle Programs require robust reserves**
  - Industry's estimating tools are ill suited to one of a kind X-vehicles
  - Competitive source selection biases estimates downward
  - Competitive negotiations biases contract values downward
  - Program reserves must be adequate to cover these realities

X-Vehicle Contracting

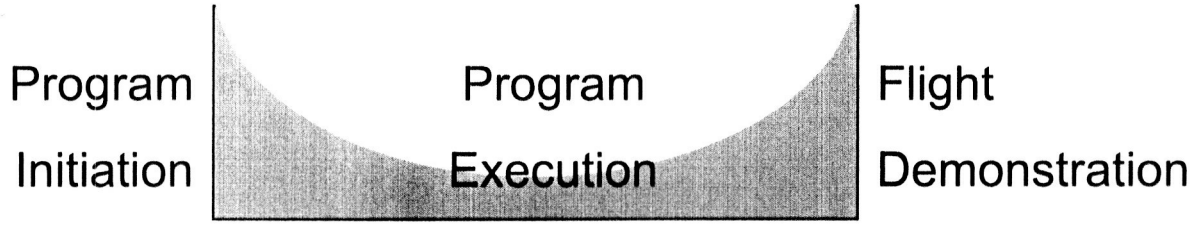
Program	Original Projected Cost	Contract Mechanism	Contract/Customer Environment
DC-X	$45M	Cost Plus Zero Fee	Cooperative & Flexible
DC-XA	$50M	3 Cooperative Agreements	Cooperative & Flexible
X-33	$850M	1 Cooperative Agreement	- - -
X-34	$94M	Fixed Price Contract	- - -
X-36	$17M	Task Order Contract	Very Flexible
X-37	$140M	1 Cooperative Agreement	- - -
X-40	$8M	Cost contract	Flexible/Hands Off Customer
X-43A-LS	$675K	Fixed Price SBIR	- - -
X-43A	$168M	Cost contract	- - -

X-Vehicle Guidelines (1-4)

- **1) X-Vehicles should have a focused technology thrust**
- **2) Modification of, or scale up from, existing vehicles substantially lowers risk**
- **3) X-Vehicles require robust reserves**
- **4) The contracting mechanism and environment must be flexible**
  - It is an invalid assumption that everything can be identified and negotiated at contract initiation
  - Both the government and industry partner must be willing to make changes at appropriate times throughout the program life
    - Contractor should not be rewarded for poor performance
    - Contractor should not bear all of the cost risk

The "Right" Government Role

- **Flight demonstration programs have three primary phases**
  - Program Initiation/Requirements Generation (ATP-SRR-PDR)
  - Program Execution
  - Flight Demonstration
- **The government's role in Program Initiation**
  - Paramount responsibility for requirements generation/approval
  - Significant participation in program planning
    - Determining support role for the government
    - Establishing resources expenditure plan
    - Establishing key program milestones/technical performance measures
- **The government's role in Program execution**
  - Insight into program's progress
  - Support of the program through application of government unique tools, facilities, and expertise
- **The government's role in the Flight Demonstration**
  - Safety is number one---liability usually passes to the government
    - Personnel
    - High Value and Unique Facilities at test ranges
    - Safety of the flight article---because we have a large investment in it
  - Support of the program through application of government unique tools, facilities, and expertise
  - Insight into program's progress



X-Vehicle Guidelines (1-5)

- 1) X-Vehicles should have a focused technology thrust
- 2) Modification of, or scale up from, existing vehicles substantially lowers risk
- 3) X-Vehicles require robust reserves
- 4) The contracting mechanism and environment must be flexible
- 5) The government must perform the "Right" Role